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Originally published at:
Batelaan, Okke; Kooistra, Lammert; Bertels, Luc; Verbeiren, Boud; Hung, Le Quoc; Deronde, Bart; Bogaert, Jan; Schaepman, Michael E (2006). Hydro-ecological modelling supported by imaging spectroscopy. In: Airborne Imaging Spectroscopy Workshop, Bruges (B), 10 October 2006. Belspo, online.

Hydro-ecological modelling supported by imaging spectroscopy

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In this contribution results are presented from imaging spectroscopy (IS), using CASI-ATM, HyMap and AHS data, for hydro-ecological modeling from a multi-disciplinary team working on different areas in Belgium and The Netherlands. Hydro-ecology is in need of detailed spatial data with respect to the occurrence of vegetation types and their determining abiotic site conditions. Recent advances in remote sensing have shown that IS can be applied for the retrieval of relevant vegetation variables (e.g., Leaf Area Index, Net Primary Production, Plant Functional Type) to monitor the actual vegetation status. As a next step, it has been demonstrated that spatially explicit variables derived from IS combined with ecological process models can be adopted to assess and forecast the future state of the landscape.

Prerequisite to ecohydrological characterization and modeling is accurate and detailed mapping of vegetation. Hyperspectral imagery (AHS) imposes challenging requirements to a classifier. The common used Spectral Angle Mapper (SAM) is a suitable technique to distinguish classes that are rather easily separable. However, when subtle differences between plant species or plant associations must be detected, SAM may not be satisfactory. To solve the problem, a classification algorithm based on Linear Discriminant Analysis (LDA) was applied. This is a statistical method to find the linear combination of features which best separate two or more classes. For the Doode Bemde floodplain mire (Belgium) 12 classes were considered while for the Millingerwaard, The Netherlands, 8 classes were considered. For both sites a number of in-situ collected ground truth data was used to train the classification algorithm. The overall weighted accuracy calculated for the Doode Bemde was 96% with a kappa of 0.96, for the Millingerwaard the overall weighted accuracy was 95% with a kappa of 0.95. When the Millingerwaard was classified according 11 ‘finer’ classes, the overall accuracy dropped to 83% with a kappa of 0.80. Nevertheless, this are still very promising results.

For the hydrological conditions of a site it is most interesting to develop tools which allow mapping the spatial distribution of soil moisture, groundwater depth and evapotranspiration fluxes. For the Doode Bemde site, it is shown that IS and thermal data can be used successfully with the SEBAL model to determine in high detail spatial differences in evapotranspiration. The imagery and model derived evaporative fraction shows a non-linear relationship with soil moisture. Hence, it offers potential to map spatially detailed soil moisture. From both CASI as well as AHS data the reflection at the red-edge inflection point is statistically shown to be a good proxy for the average groundwater depth of different phreatophytic vegetation types in the Doode Bemde.

Two further examples show how IS can be adopted to map vegetation structure types in a dune valley ecosystem and to estimate aboveground net primary production (ANPP) in a river floodplain ecosystem. The first example shows how a method commonly used for ecological statistical analysis can be used for band selection by combining IS data and plant species data. The use of Redundancy Analysis in combination with maximum likelihood classification resulted in a sufficient overall accuracy (69%) for classification of 6 vegetation structure types in the dune valley systems of

Ameland. In the second example we compare HyMap derived ANPP with ANPP estimates derived from the dynamic vegetation model SMART2-SUMO2 for 21 points for which ground data were available to initialize the vegetation model. The HyMap and model derived ANPP show a satisfactory agreement ($r = 0.728$). The results of this study demonstrate that IS derived products can be used for validation and initialization of vegetation models. Especially, the inclusion of more reliable and site-specific estimates of the input-data, increases the reliability of model output.

Finally, a research outlook is given on spatial pattern analysis for deepening our knowledge on the use of IS for ecological modelling. Application of fragmentation indices can enhance confidence in remote sensing information, since aggregated patterns are considered to represent more reliable and ecologically relevant information than observations present with a fragmented spatial pattern. The use of fragmentation metrics originating from landscape ecology for application on satellite-based information is therefore appealing and further investigated.

It is concluded that the results of this multi-disciplinary research clearly contribute to a wider set of tools for ecohydrological analysis, as well as contribute to an increased understanding of the ecohydrological functioning of the studied areas.